CLAIMS

1. A wave transmission medium for outputting incident light that is launched into an input side port (input port) to a desired output side port (output port), said port being defined as a location of a circuit at which a cross section having desired optical input/output is given, said wave transmission medium comprising:

a spatial refractive index distribution determined such that the incident light launched into the input port propagates through the wave transmission medium with scattered multiple times;

wherein local positions in the wave transmission medium are designated by virtual pixels defined by a virtual mesh, and

the spatial refractive index distribution of the wave transmission medium is formed by refractive indices of the individual pixels.

2. The wave transmission medium as claimed in claim 1, wherein the refractive index distribution of said wave transmission medium is set such that a phase of a forward propagating field of the incident light launched into the input port matches a phase of a reverse propagating field of emitted light phase conjugation of at individual points of said wave transmission medium.

3. The wave transmission medium as claimed in claim 1 or 2, wherein the refractive indices said pixels can take is one of a low refractive index (n_L) or a high refractive index (n_H), and

said refractive index distribution is given by spatially placing pixels with the low refractive index (n_L) and pixels with the high refractive index (n_H).

4. The wave transmission medium as claimed in claim 3, wherein the pixels with the low refractive index (n_L) have an existing probability of equal to or less than 30% in a propagation direction of the incident light in said wave transmission medium.

5. The wave transmission medium as claimed in claim 1 or 2, wherein said pixels can take a finite number of refractive indices between a lower limit refractive index and an upper limit refractive index, and

said refractive index distribution is given by spatially placing pixels with the refractive indices selected from among the finite number of refractive indices.

6. The wave transmission medium as claimed in any one of claims 1-5, wherein said refractive index distribution is determined such that the incident light launched into the input port is split to different output

port locations at a desired ratio.

7. The wave transmission medium as claimed in any one of claims 1-6, wherein the incident light launched into the input port is wavelength division multiplexed light composed of a plurality of wavelengths, and said refractive index distribution is determined such that the optical waves are demultiplexed to different output port locations depending on the individual wavelengths of the wavelength division multiplexed light.

8. The wave transmission medium as claimed in any one of claims 1-6, wherein the incident light launched into the input port is wavelength division multiplexed light composed of a plurality of wavelengths, and said refractive index distribution is determined such that the wavelength division multiplexed light are demultiplexed and split to different output port locations at a desired ratio.

9. The wave transmission medium as claimed in any one of claims 1-6, wherein the incident light launched into the input port is polarization multiplexed light with a TE mode and TM mode, and said refractive index distribution is determined such that the polarization multiplexed light is demultiplexed to different output port locations depending on individual polarized waves

of the polarization multiplexed light.

10. The wave transmission medium as claimed in any one of claims 1-6, wherein the incident light launched into the input port is polarization multiplexed light with a TE mode and TM mode, and said refractive index distribution is determined such that individual polarized waves of the polarization multiplexed light are demultiplexed and split to different output port locations at a desired ratio.

11. The wave transmission medium as claimed in any one of claims 1-10, wherein said wave transmission medium is composed of a dielectric.

12. A fabrication method of the wave transmission medium as defined in any one of claims 1-11, said fabrication method comprising:

a first step of obtaining, in said wave transmission medium with an assumed initial refractive index distribution, a field distribution 1 of the incident light and a field distribution 2 resulting from the emitted light virtually transmitted from the output port in a reverse direction;

a second step of determining said refractive index distribution such that a phase difference between the field distribution 1 and the field distribution 2 is

reduced at the individual points of said wave transmission medium; and

a third step of carrying out, at said output port locations, successive approximation of said refractive index distribution by repeating the first step and the second step until an error between the field distribution 1 and the field distribution of the emitted light becomes less than a desired value.

13. The fabrication method of the wave transmission medium as claimed in claim 12, wherein said second step determines the refractive index distribution by a steepest descent method using individual refractive indices of said pixels as variables.

14. A fabrication method of the wave transmission medium as defined in any one of claims 1-11, said fabrication method comprising:

a first routine and a second routine for carrying out successive approximation of said refractive index distribution,

said first routine including:

a first step of obtaining, in said wave transmission medium with an assumed initial refractive index distribution, a field distribution 1 of the incident light and a field distribution 2 resulting from the emitted light virtually transmitted from the output

port in a reverse direction;

a second step of revising said refractive index distribution such that the phase of the field distribution 2 matches the phase of the field distribution 1 at the locations in said wave transmission medium;

a third step of reobtaining the field distribution 2 at the locations using the revised refractive index distribution;

a fourth step of redefining said locations as new locations by shifting said locations by a predetermined distance in the reverse propagation direction; and

a fifth step of carrying out successive approximation of said refractive index distribution by repeating first to fourth steps, and

said second routine including:

a sixth step of obtaining, in said wave transmission medium with the assumed refractive index distribution determined in said first routine, a field distribution 1 of the emitted light (incident light) and a field distribution 2 resulting from the emitted light virtually transmitted from the output port in a reverse direction;

a seventh step of revising said refractive index distribution such that the phase of the field distribution 1 matches the phase of the field

distribution 2 at the locations in said wave transmission medium;

an eighth step of reobtaining the field distribution 1 at the locations using the revised refractive index distribution;

a ninth step of redefining said locations as new locations by shifting said locations by a predetermined distance in the forward propagation direction; and

a tenth step of carrying out successive approximation of said refractive index distribution by repeating sixth to ninth steps.

15. The fabrication method of the wave transmission medium as claimed in claim 14, wherein said second step uses:

as the field distribution 2, a field distribution obtained by forwardly transmitting through the refractive index distribution before the successive approximation a field distribution resulting from transmitting the emitted light to an incidence plane through the refractive index distribution before the successive approximation; and

as the field distribution 1, a field distribution obtained by reversely transmitting through the refractive index distribution before the successive approximation a field distribution resulting from

transmitting the incident light to an emitting plane through the refractive index distribution before the successive approximation.

16. The fabrication method of the wave transmission medium as claimed in claim 14 or 15, further comprising a third routine of repeating said first routine and said second routine sequentially until an error between the field distribution 1 and the emitted light field distribution at the output port locations becomes less than a desired value.

17. The fabrication method of the wave transmission medium as claimed in any one of claims 12-16, wherein said field distribution 1 and said field distribution 2 each incorporate reflected light components of the incident light and reverse propagation light through said wave transmission medium.

18. The fabrication method of the wave transmission medium as claimed in any one of claims 12-17, wherein said initial refractive index distribution is assumed to be a random distribution.

19. The fabrication method of the wave transmission medium as claimed in any one of claims 12-18, wherein the incident light launched into the input port

is wavelength division multiplexed light consisting of optical waves with a plurality of wavelengths, or polarization multiplexed light consisting of polarized waves with a TE mode and a TM mode;

the successive approximation of said refractive index distribution is carried out sequentially using the field distribution 2 that is defined for each of the optical waves with the individual wavelengths or for each of the individual polarized waves of the multiplexed light; and

said refractive index distribution is determined such that the optical waves constituting said multiplexed light are demultiplexed to different output port locations at a desired ratio.

20. A waveguide circuit that is configured by two-dimensional placement of the wave transmission medium as defined in any one of claims 1-11 on a substrate.

21. A waveguide circuit constituting a multimode interference circuit using the waveguide circuit as defined in claim 20.

22. An optical circuit constituting an optical bending circuit using the waveguide circuit as defined in claim

23. An optical circuit configured by using the waveguide circuit as defined in claim 20, wherein the refractive index distribution of said waveguide circuit is implemented by local refractive index variations of said waveguide circuit based on electrooptic effect.

24. An optical circuit configured using the waveguide circuit as defined in claim 20, wherein

individual refractive indices of said pixels are determined such that the light is confined in a direction perpendicular to said substrate.

25. The optical circuit as claimed in claim 24, wherein said virtual mesh is composed of configuration elements of a unit cell that form the waveguide region in periodic repetition.

26. The optical circuit as claimed in claim 24 or 25, wherein said unit lattice has a quasi-periodic structure.

27. The optical circuit as claimed in any one of claims 24-26, wherein said pixels can take one of two refractive index values of a high refractive index (n_H) and a low refractive index (n_L).

28. The optical circuit as claimed in claim 27, wherein said pixels with the high refractive index have a size equal to or less than a wavelength of the light propagating through said waveguide region.

29. The optical circuit as claimed in claim 27 or 28, wherein a value given by the following expression is equal to or less than 0.1,

$$\frac{\lambda q}{\pi n a}$$

where λ is the wavelength of the propagation light, n is the refractive index (n_H) of the pixels with the high refractive index, a is the height of the pixels with the high refractive index, and q is a coefficient given by q = (z/a) where z is an average distance of radiation components of the field distribution of the propagation light.

30. The optical circuit as claimed in any one of claims 24-29, wherein said pixels with the high refractive index has a shape of a polygon with n sides, where n is an integer equal to or greater than three, and wherein said pixels are placed such that the sides each have an inclination with respect to the propagation direction of the light propagating through the waveguide region.

31. The optical circuit as claimed in claim 30, wherein said shape of a polygon is a square, and an angle of the inclination is 45 degrees.

32. The optical circuit as claimed in any one of claims 24-31, wherein said pixels each have a desired size equal to or greater than the region defined by the virtual mesh, and some of said pixels are placed at locations deviated from lattice locations defined by the virtual mesh.

33. The optical circuit as claimed in any one of claims 27-32, wherein said pixels with the high refractive index (n_H) comprises a waveguiding section including a first high refractive index layer and a second high refractive index layer which are stacked sequentially, said second high refractive index layer having a refractive index lower than the first high refractive index layer; and said pixels with the low refractive index (n_L) comprises a waveguiding section composed of said second high refractive index layer, and wherein a center of a diameter of the optical field propagating through the waveguiding section of the pixels with the high refractive index (n_H) and a center of a diameter of the optical field propagating through the waveguiding section of the pixels with the low refractive index (n_L) are both placed on a same plane parallel to a surface

of the substrate.

34. The optical circuit as claimed in any one of claims 24-33, wherein said waveguide region is composed of a dielectric material that has an optical loss function or optical amplification function.

35. The optical circuit as claimed in claim 34, wherein said dielectric material has a complex refractive index depending on the wavelength of light.

36. The optical circuit as claimed in any one of claims 24-35, wherein said waveguide region has a structure comprising a first low refractive index layer, a high refractive index layer constituting the waveguide section and a second low refractive index layer, which are stacked sequentially, and wherein the light is confined in said high refractive index layer by the first and second low refractive index layers.

37. The optical circuit as claimed in claim 36, wherein

said high refractive index layer has, on its one of surface, relief-like patterning formed by creating concave portions, and wherein

said spatial refractive index distribution is implemented by employing the concave portions as the low refractive index section, and regions other than

the concave portions as the high refractive index section.

38. The optical circuit as claimed in claim 37, wherein said relief-like patterning is formed on both surface of said high refractive index layer.

39. The optical circuit as claimed in claim 38, wherein the relief-like patterns formed on both sides of said high refractive index layer have patterns different from each other.

40. The optical circuit as claimed in claim 38 or 39, wherein said concave portions of the relief-like patterns formed on both sides of said high refractive index layer have a same depth.

41. The optical circuit as claimed in any one of claims 24-40, wherein said pixels are each divided into a plurality of virtual sub-pixels having one of the high refractive index (n_H) and the low refractive index (n_L), and said refractive index distribution of the pixels are implemented by arrangement of the sub-pixels with the two refractive indices.

42. The optical circuit as claimed in any one of claims 24-41, wherein in said pixels, a refractive index

difference is varied over a distance equal to or greater than one wavelength as a rate of change of the refractive index difference, as a rate of spatial change of a propagation constant in the proceeding direction of a wavefront of the propagation light.

43. The optical circuit as claimed in claim 42, wherein said pixels or said sub-pixels each have a circular cross section in a direction parallel to said substrate.

44. The optical circuit as claimed in claim 42 or 43, wherein said pixels or said sub-pixels each have a cross section with a shape of smoothly varying curve in a direction perpendicular to said substrate.

45. The optical circuit as claimed in any one of claims 36-44, wherein at least one of said first and second low refractive index layers is formed by stacking a plurality of layers with different refractive indices.

46. The optical circuit as claimed in any one of claims 24-45, wherein said optical circuit consists of an optical circuit with a mutual broadcast delivery/broadcast reception configuration having at least three input/output ports, and wherein

said spatial refractive index distribution is established such that phases of signals output from said

input/output ports are perpendicular to each other.

47. The optical circuit as claimed in any one of claims 24-45, wherein said optical circuit consists of an optical circuit with a mutual broadcast delivery/broadcast reception configuration having at least three input/output ports, and wherein

said spatial refractive index distribution is established such that when phases of signals output from said input/output ports are not perpendicular to each other, overlaps of the output signals become minimum.

48. The optical circuit as claimed in claim 46 or 47, wherein a branching ratio of said optical circuit is asymmetric.

49. The optical circuit as claimed in any one of claims 46-48, wherein the foregoing optical circuit comprises an amplification function.

50. The optical circuit as claimed in any one of claims 24-49, wherein

said optical circuit includes a plurality of input ports, and is configured such that input optical signals launched into the plurality of input ports are output from a same emitting plane, and wherein

said spatial refractive index distribution is

established such that the individual optical signals output from the plurality of input ports have their phases adjusted to be aligned with each other, in order to shape a profile of the output optical field.

51. An optical circuit having the optical circuit as defined in claim 50 placed at an input side slab of an arrayed waveguide grating circuit, wherein

mutual phase differences between the plurality of input ports are given by circuit lengths of the optical waveguides of said optical circuit; and

a repetition period (free spectrum range) of the phase differences given by the circuit lengths of said optical waveguides agrees with a wavelength spacing of outputs of said arrayed waveguide grating circuit, and centers of fields of the outputs of said optical circuit vary periodically to cancel out chromatic dispersion characteristics of said arrayed waveguide grating circuit periodically at the wavelength spacing of the outputs.

52. The optical circuit as claimed in any one of claims 24-51, wherein said spatial refractive index distribution is established such that it implements a field profile and phase distribution that enable spot size conversion of the output light.

53. An arrayed waveguide grating type optical multi/demultiplexer configured using the waveguide circuit as defined in claim 20, said arrayed waveguide grating type optical multi/demultiplexer comprising:

an input waveguide, a first slab waveguide, arrayed waveguides, a second slab waveguide and output waveguides, which are connected sequentially on a planar substrate; and

a plurality of scattering points with a refractive index higher than a refractive index of said input waveguide, said scattering points being placed in a connecting region between said input waveguide and said first slab waveguide.

54. The arrayed waveguide grating type optical multi/demultiplexer as claimed in claim 53, wherein said scattering points are disposed such that an optical field distribution formed at an output end of said input waveguide has an iso-phase wavefront without distortion, and an amplitude with double peaks.

55. The arrayed waveguide grating type optical multi/demultiplexer as claimed in claim 53, wherein said scattering points have in said input waveguide a two-dimensional configuration that has nearly line symmetry with respect to a line extending to the propagation direction of light.

56. The arrayed waveguide grating type optical multi/demultiplexer as claimed in any one of claims 53-55, where said scattering points each have a side equal to or greater than 0.2 μm.

57. The arrayed waveguide grating type optical multi/demultiplexer as claimed in any one of claims 53-56, wherein said planar substrate consists of a silicon substrate, and said optical waveguides consist of silica-based glass optical waveguides.